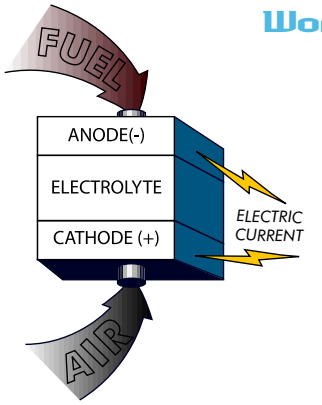
ARGONNE NATIONAL LABORATORY

Hydrogen-Powered Fuel Cells for a Cleaner, More Secure Energy Future

Hydrogen is expected to play a key role in the Nation's energy future by replacing fossil fuels. This shift to a "hydrogen economy" would help secure our energy future and our environment by reducing our dependence on imported oil, reducing pollution from fossil fuels, and reducing the emission of greenhouse gases. Unlike fossil fuels, however, hydrogen must be manufactured, and to do so requires energy. If we are to realize a hydrogen economy, we must have enough clean energy to manufacture hydrogen. Nuclear power is seen by many as the most promising of the energy technologies that offer secure long-term fuel supplies and do not produce greenhouse gases.

How a Fuel Cell Works



A fuel cell produces electricity from hydrogen and oxygen. Hydrogen is the most abundant element on Earth, but before it can be used in fuel cells it must first be derived from water or hydrocarbons such as gasoline, propane, natural gas, methanol, and ethanol. Oxygen is obtained from the air.

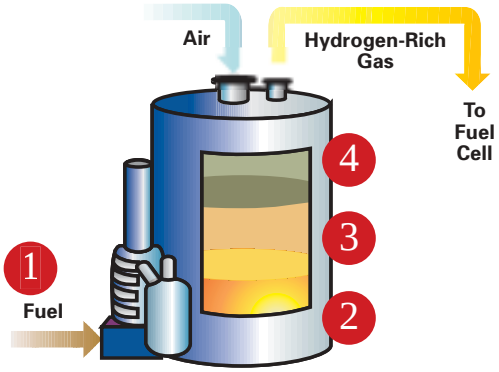
Fuel Cells Provide Clean Energy

One important use for hydrogen is powering fuel cells, which can produce clean, emission-free energy by converting hydrogen gas and air into electricity and water – a very clean and efficient system compared with internal combustion engines. Fuel cells can be used to produce electricity and generate heat for buildings.

Making Hydrogen Today: Argonne's Fuel-Reforming Technology

Several major manufacturers have developed hydrogen-powered fuel-cell systems for powering vehicles and homes, but hydrogen is not yet convenient to use as a fuel.

Argonne National Laboratory has developed a device that can serve as a transition technology until hydrogen is readily available. Argonne's compact, efficient fuel processing technology is "fuel flexible," meaning it can "reform" many conventional hydrocarbon fuels, such as gasoline, methanol, and natural gas, into a hydrogen-rich gas for use in fuel cells. Argonne's fuel processor is an inexpensive, easy-to-manufacture device that reforms conventional fuels into hydrogen using a process similar to that used in today's automotive catalytic



converters. Vaporized fuel (1) is mixed with steam and air and sent through a catalyst-packed cylinder. The first-stage catalyst (2) releases hydrogen to feed the fuel cell. Carbon monoxide created by this reforming process is used to make additional hydrogen as it passes through a second-stage catalyst (3) and a cartridge absorbs sulfur (4).

In the first stage of the system is a new partial oxidation catalyst developed by Argonne that is based on a unique combination of selected metals and an oxygen-conducting ceramic material. When the fuel/air mixture contacts the catalyst, hydrogen is released from the fuel at temperatures that are several hundred degrees lower than with conventional processes. In addition to its fuel-flexible capability, the catalyst has shown excellent resistance to sulfur (a substance that degrades fuel-cell performance and is often found in fuels). Sulfur tolerance is essential for reliable, long-term fuel cell operation.

"The President's Plan directs us to explore the possibility of a hydrogen economy."

—Spencer Abraham, Secretary of Energy

Generating Hydrogen in Tomorrow's Hydrogen Economy

In addition to hydrogen generation, there are technical challenges associated with hydrogen distribution and storage, and with hydrogen use. Argonne National Laboratory addresses all of these issues by conducting a wide range of research.

Argonne National Laboratory is developing technologies that can facilitate hydrogen generation for many applications.

Near-Term Solutions: Until large quantities of hydrogen can be readily and reliably available to consumers for use in powering their vehicles and homes, fossil-fuel-based transition technologies, such as Argonne's fuel processor, will be needed. Some of these technologies will power fuel cells by making hydrogen from gasoline (onboard fuel-cell-powered vehicles) or making hydrogen from propane, natural gas, ethanol, or other fossil fuel (inside dishwasher-sized fuel-cell units used for residential power applications). Other fossil-fuel-based technologies might involve larger, centralized hydrogen-production facilities. Argonne's fossil-fuel-based technologies for generating hydrogen include ceramic-membrane conversion, partial-oxidation catalytic reforming, and coal gasification and carbon sequestration.

Mid-Term Solutions: Hydrogen can be made locally from water using a process called electrolysis, which splits the water into its separate hydrogen and oxygen elements in a non-polluting process. Electrolysis does require energy to operate, but this can be obtained off the power grid from clean energy sources, such as nuclear power plants, or from other renewable power sources. Argonne is exploring additional technologies for generating hydrogen, including methane pyrolysis and biophotolysis/nanocatalysis.

Long-Term Solutions: When sufficient infrastructure systems (pipelines, tankers, retail stations) for distributing, transporting, and storing bulk hydrogen are in place, hydrogen can then be produced from water at large, central plants using more efficient chemical processes and heat or power from nuclear power plants. The hydrogen produced can be immediately sent through large fuel-cell systems to produce electricity or it can be stored for later use during times of peak electricity demand. Argonne's nuclear-based technologies for generating hydrogen include thermal cracking of water.

Hydrogen Distribution, Storage, and Use

Argonne is studying advanced methods of transporting and storing hydrogen, as well as the economic, energy, and emission implications of widespread use of hydrogen in transportation applications. The research includes evaluating the current infrastructure for transporting hydrogen and determining ways to accelerate its introduction into the transportation sector. This research includes testing of hydrogen vehicles.

The Role of Nuclear Energy in a Hydrogen Economy

Every method of producing hydrogen requires some source of energy. The advantage of using hydrogen is that it burns cleanly when used to produce electricity. Shifting to a hydrogen economy would not offer much of an advantage if the hydrogen-making process itself produced greenhouse gases. This is where nuclear energy can play a role.

Limited fossil energy resources and environmental issues are expected to increase the significance of non-fossil energy sources, including nuclear. Of the energy technologies that offer secure long-term supplies of fuel and do not produce greenhouse gases, many today see nuclear power as the most promising.

Nearly 500 nuclear power plants are in operation or under construction worldwide. The development of next-generation reactor designs for simultaneously generating electricity and heat makes nuclear-powered hydrogen-generating plants a viable long-term solution.

For More Information

Visit Argonne's G8 Energy Conference web site (www.anl.gov/G8) or contact Dr. James F. Miller (630-252-4537, millerj@cmt.anl.gov) or Dr. David Lewis (630-252-4383, lewisd@cmt.anl.gov).

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